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Pressure-Vessel-Damage Fluence Reduction by Low-Leakage Fuel Management*

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As a result of neutron-induced radiation damage to the pressure vessel and of an increased concern that in a PWR transient the pressure vessel may be subjected to pressurized thermal shock (PTS),[1] detailed analyses have been undertaken to determine the levels of neutron fluence accumulation at the pressure vessels of selected PWR's.[2] In addition, various methods intended to limit vessel damage by reducing the vessel fluence have been investigated. This paper presents results of the fluence analysis and the evaluation of the low-leakage fuel management fluence reduction method.

The calculations were performed with DOT-3.5[3] in an octant of the core/shield/vessel configuration using a 120x43 (r,θ) mesh structure. An S_8 angular quadrature and P-3 approximation were used with the RSIC DLC-37/EPR (100-Group, ENDF/B-IV) cross section library.[4] DOT region-wise cross sections were determined with the ANISN[5] code. The neutron source was determined from a time averaged assembly-wise power distribution.

The calculations have been carried out for a Babcock & Wilcox 177-assembly core, a Combustion Engineeering 133-assembly core and a Westinghouse 157-assembly core. The conclusions are qualitatively the same for the three plants and only the results for the Westinghouse 157-assembly core will be presented here.

Since the neutron flux at the inner wall of the pressure vessel is dominated by the power in the peripheral assemblies, the core neutron source distribution is conveniently characterized by the ratio of the peripheral to core average asssembly power, P_p/P_c. In addition to the base case (LL-1) in which the present core neutron source distribution characterized by a P_p/P_c = 0.89 was used, two low leakage cases were calculated; an intermediate low-leakage case (LL-2) with P_p/P_c = 0.45 and an extreme low-leakage case (LL-3) with P_p/P_c = 0. For the base case the core neutron source was derived from a typical operating assembly-wise power distribution. The source distribution for the intermediate low-leakage case (LL-2) was derived from the base case by reducing the peripheral power by 50%, the next innermost row by 10% and increasing the central core power accordingly. In the extreme low-leakage case (LL-3) the peripheral power was taken to be zero. In this case, the next innermost row of assemblies became peripheral assemblies and were accordingly reduced in power.

In Figure-1 the reduction in vessel end-of-life (EOL) fluence is presented as a function of peripheral assembly power assuming (a) the low-leakage configuration is implemented at beginning of vessel life (solid curve) and (b) the low-leakage configuration is implemented after $\sim$ 7 effective full power years (EFPY) of operation in a typical (P_p/P_c = .89) operating power distribution (dashed curve).

The reduction in vessel fluence is accomplished by shifting the core power distribution away from the periphery and toward the core center, and results in an increase in the power in the center of the core. Peak power increases of ~ 20% and ~ 30% will result for the intermediate and extreme low-leakage cases, respectively, but it is expected that such peak power increases may be reduced substantially by flattening the power in the center of the core. It should be noted, however, that if the peripheral assembly power reduction is accomplished by loading twice or thrice burned fuel on the periphery, the resulting increase in multiplication and hardening of the spectra will reduce the low-leakage fluence reduction by ~ 0-15%.

In Figure-2 the vessel EOL fluence is given for the two low-leakage schemes assuming implementation at ~ 7 EFPY. The low-leakage scheme in which the peripheral power is reduced by a factor of ~2 will result in an ~ 50% reduction in EOL fluence. In the extreme low-leakage scheme a fluence reduction by a factor of ~4 can be achieved. While the fluence reductions obtained are accompanied by some loss in core power peaking margin, it is concluded that low- leakage fuel management will reduce neutron-induced radiation damage to the pressure vessel and provides a potential means for extending vessel life.

References

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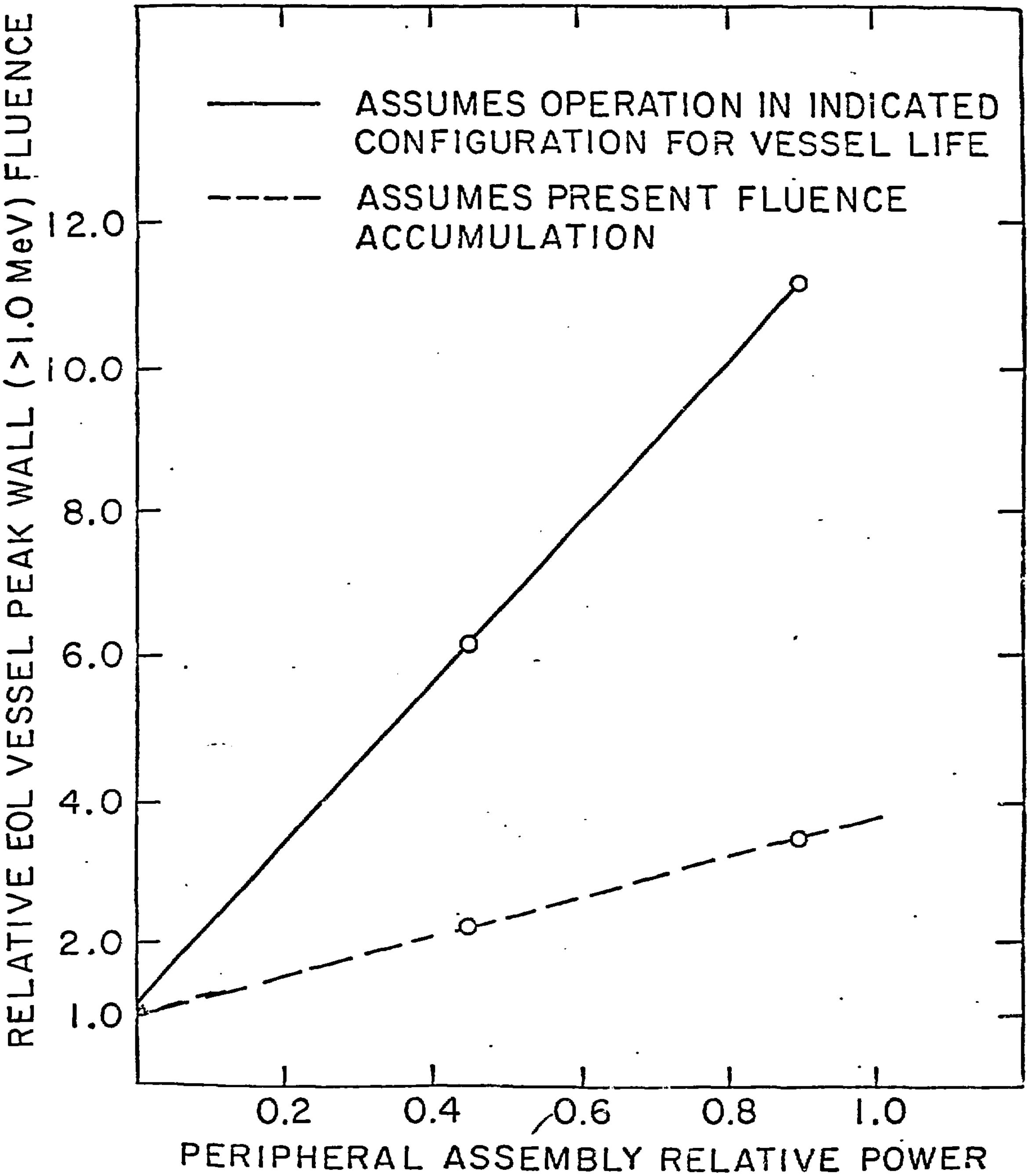

Figure-1 Low Leakage Fuel Management Fluence Reduction vs. Peripheral Assembly Relative Power For a Westinghouse 157-Assembly PWR

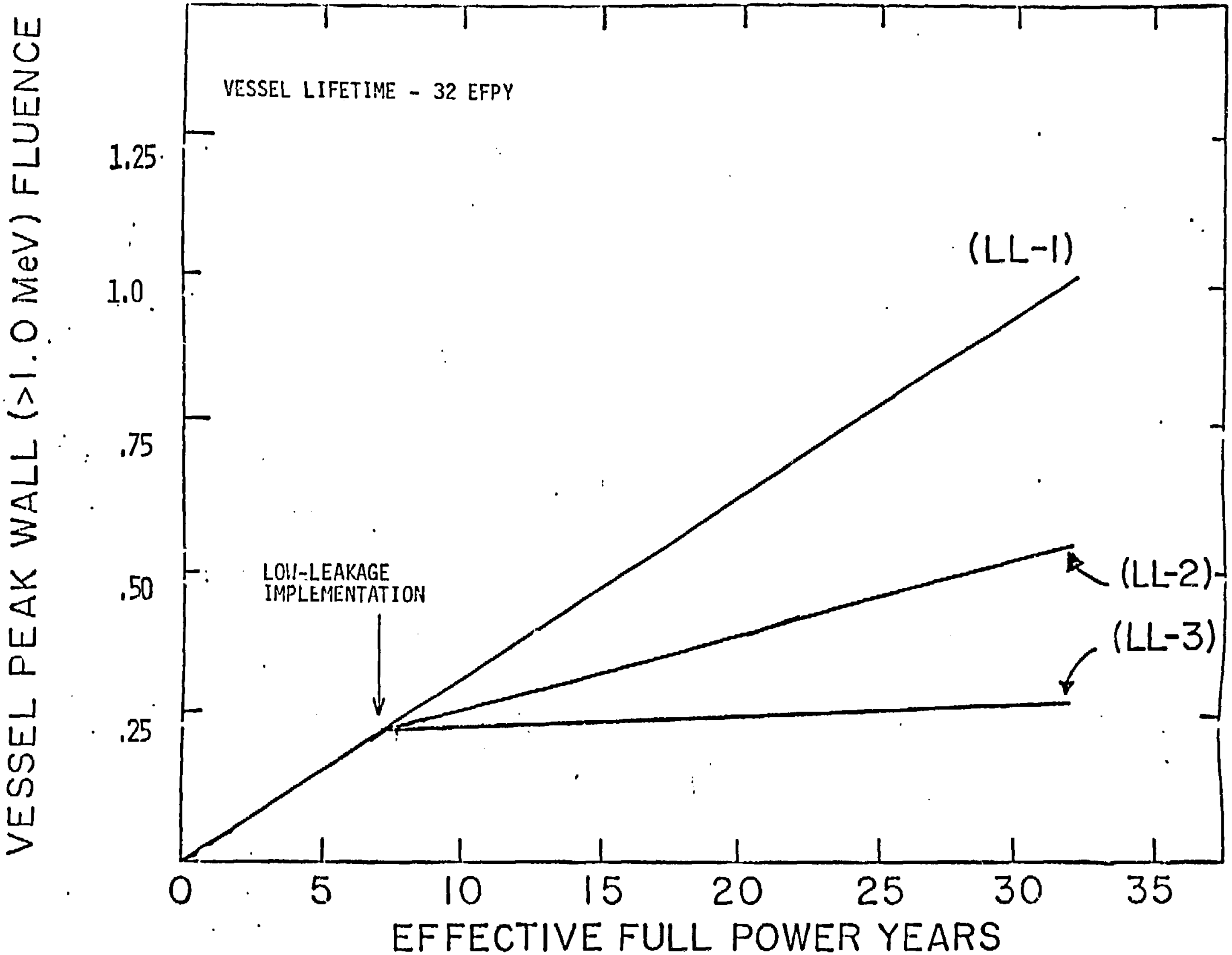

Figure-2 Westinghouse 157-Assembly PWR Relative Vessel Peak Wall Fluence (PWF) vs. Effective Full Power Years (EFPY)